Making Sense of the Variability of Coastal Ocean Acidification:

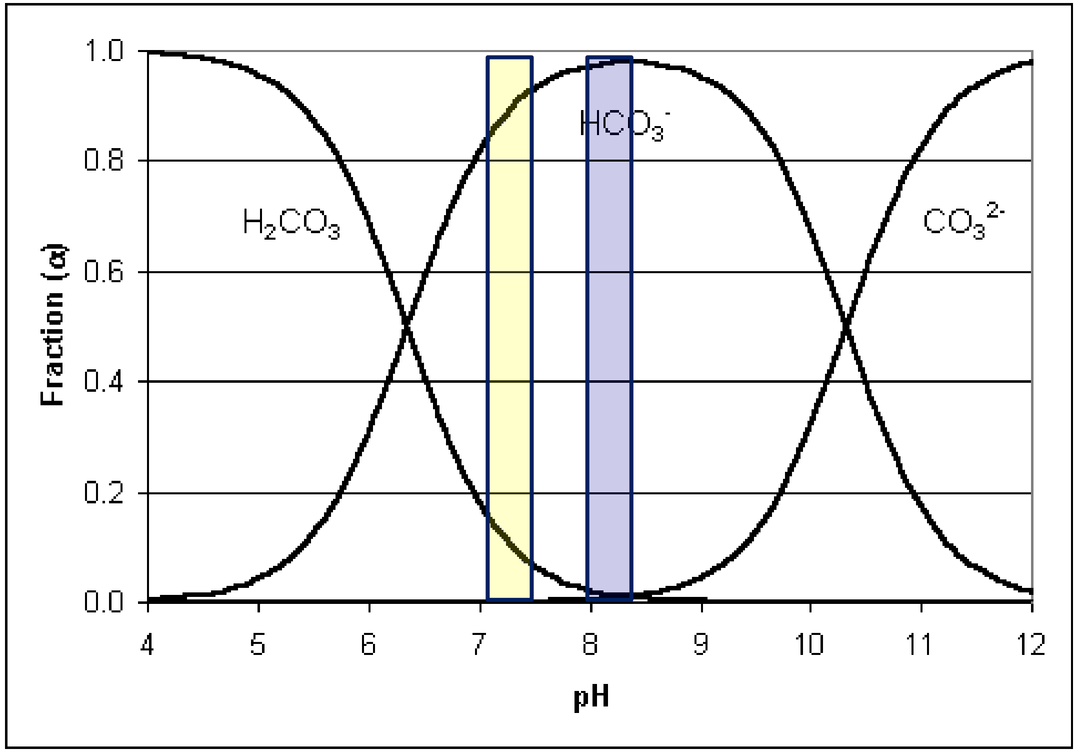
Potential Long-Term Impacts on the Oyster Aquaculture Industry

MassBays
NATIONAL ESTUARY PROGRAM

UMASS BOSTON

Measuring “Ocean Acidification”
Inorganic Carbon

- Aragonite saturation value (actually needed)



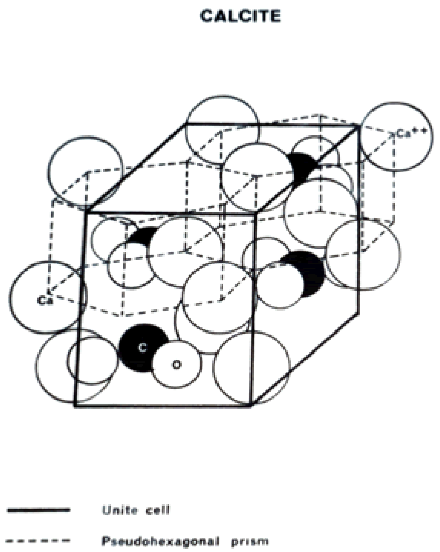
CO_2 (g) + $H_2O \Leftrightarrow H_2CO_3$
$H_2CO_3 \Leftrightarrow H^+ + HCO_3^-$
$HCO_3^- \Leftrightarrow H^+ + CO_3^{2-}$
$Ca^{2+} + CO_3^{2-} \Leftrightarrow CaCO_3(s)$
(calcite or aragonite)

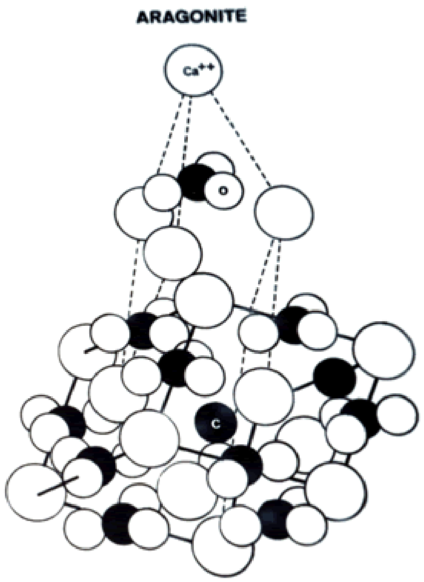
Measuring "Ocean Acidification"
Four Parameters

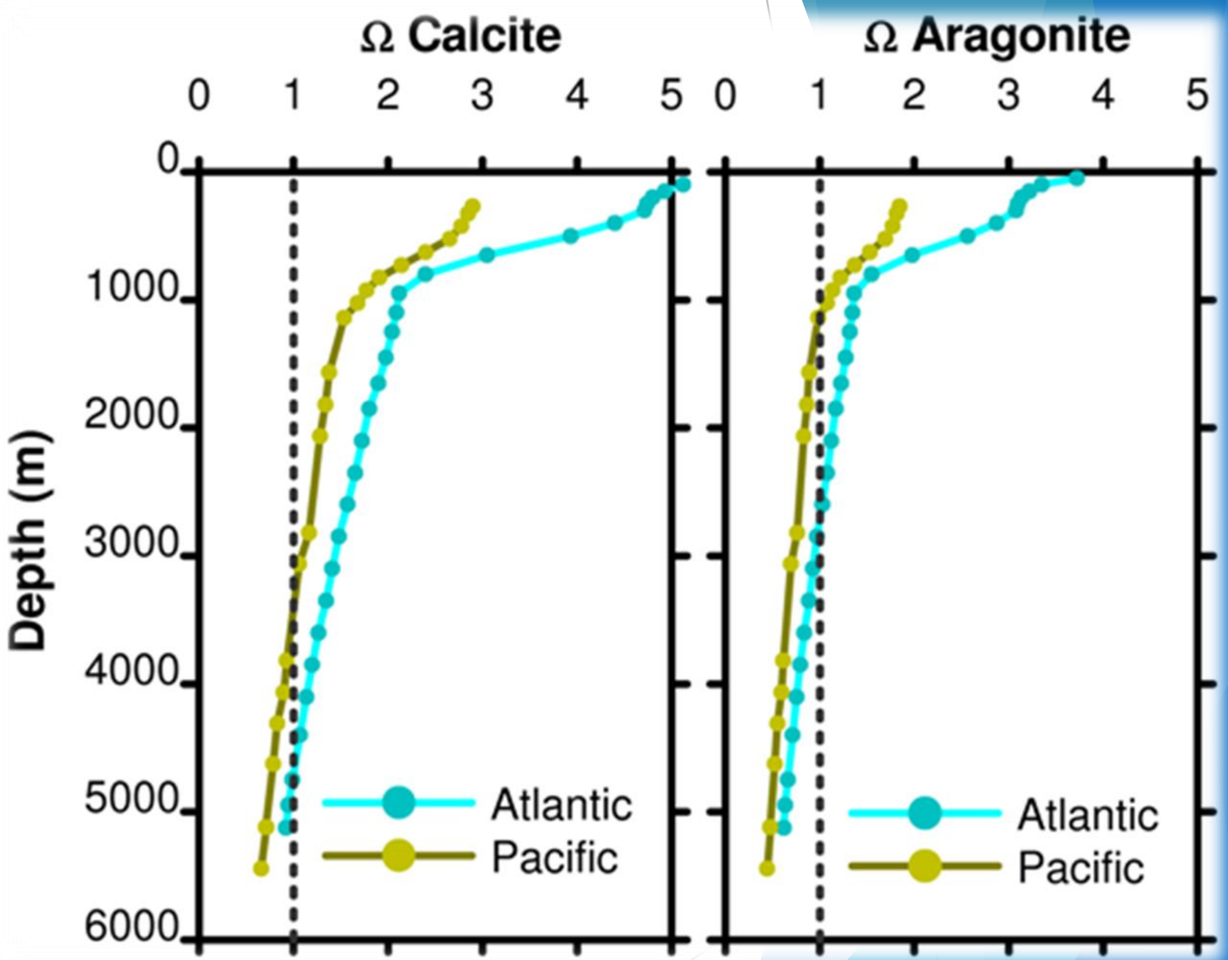
- Four parameters – Any two parameters can define carbonate speciation
  - **pH**
    - measure of hydrogen ion concentration
  - **Total Alkalinity (AT)**
    - the excess of bases (proton acceptors) over acids (proton donors) in solution
  - **Total CO2 (TCO2)**
    - measure of carbon dioxide which exists in several states
  - **pCO2**
    - the partial pressure of carbon dioxide, a measure of the relative concentration of the gas in air or in a fluid

Measuring “Ocean Acidification”

Aragonite vs Calcite







$\Omega = [Ca^{2+}]\,[CO_3^{2-}]/K_{sp}'$

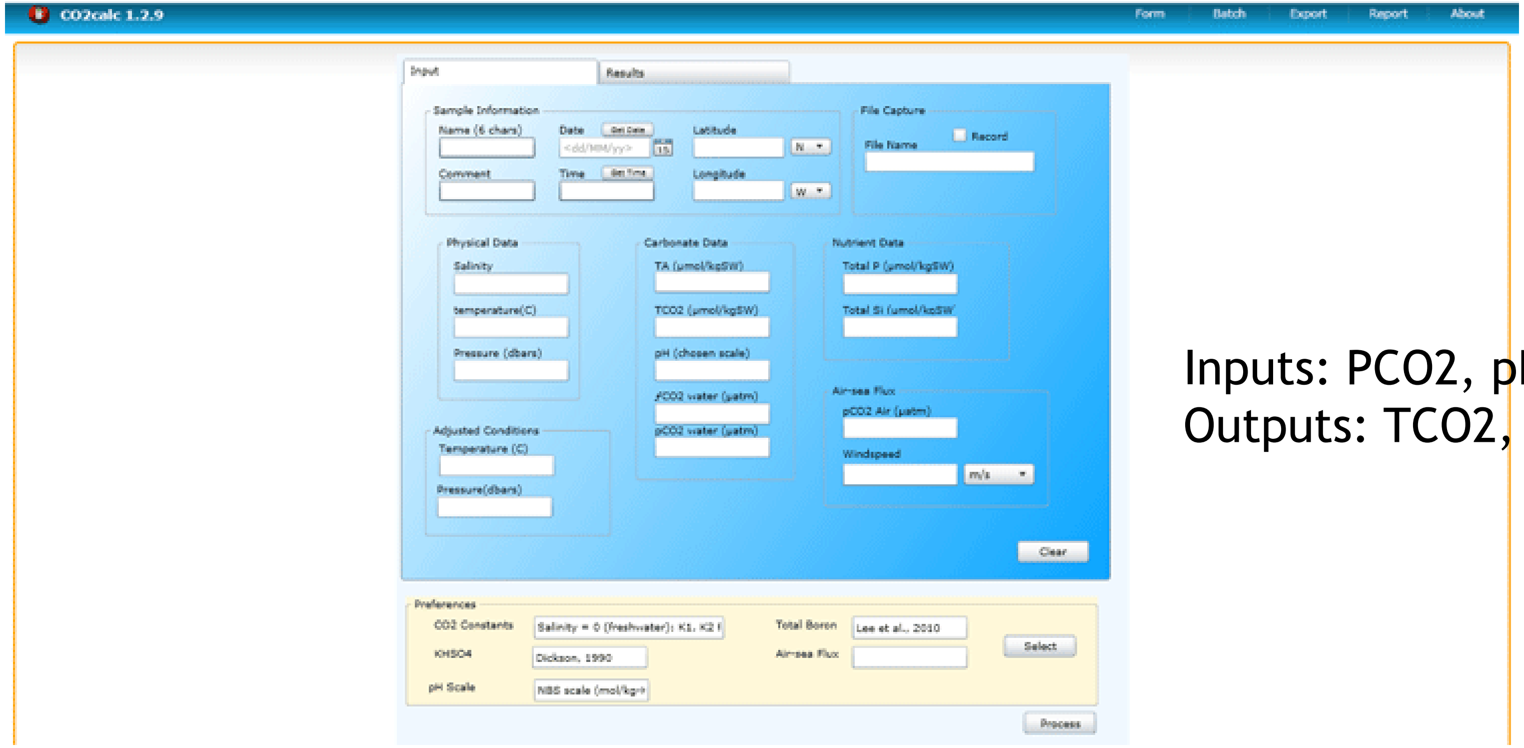
$\Omega > 1$, supersaturated $\Omega <$ undersaturated

$\Omega < 2$ can inhibit growth

Barton et al. 2012

Measuring “Ocean Acidification”

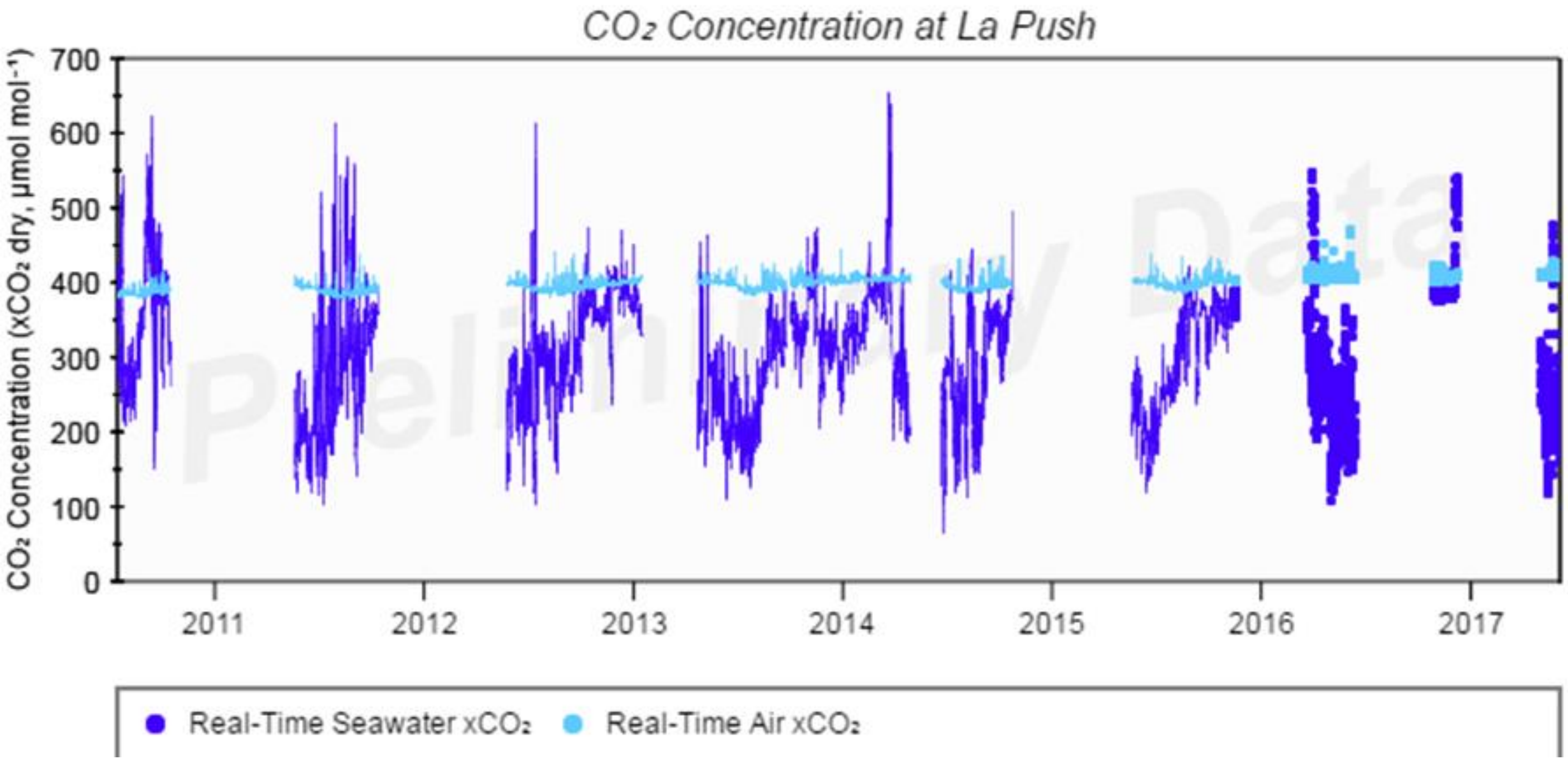
CO2 Sys



Inputs: PCO2, pH, Temperature, Salinity
Outputs: TCO2, TA, Ωar

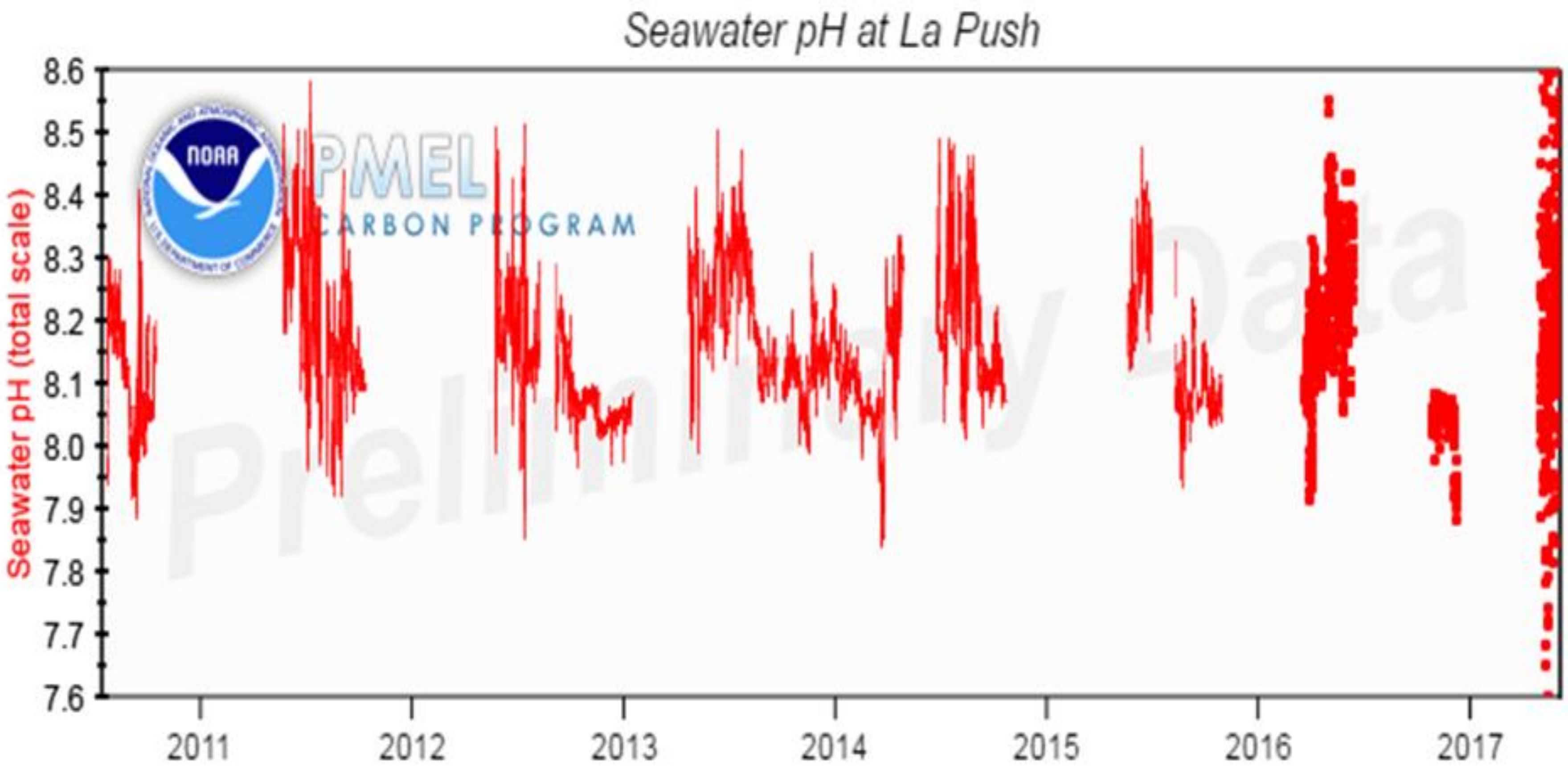
Lewis and Wallace, 1998; Pierrot et al., 2006

Variability on coastal pH and pCO2



https://www.pmel.noaa.gov/co2/story/La+Push: **showing variability in pCO_2**

Variability on coastal pH and pCO2



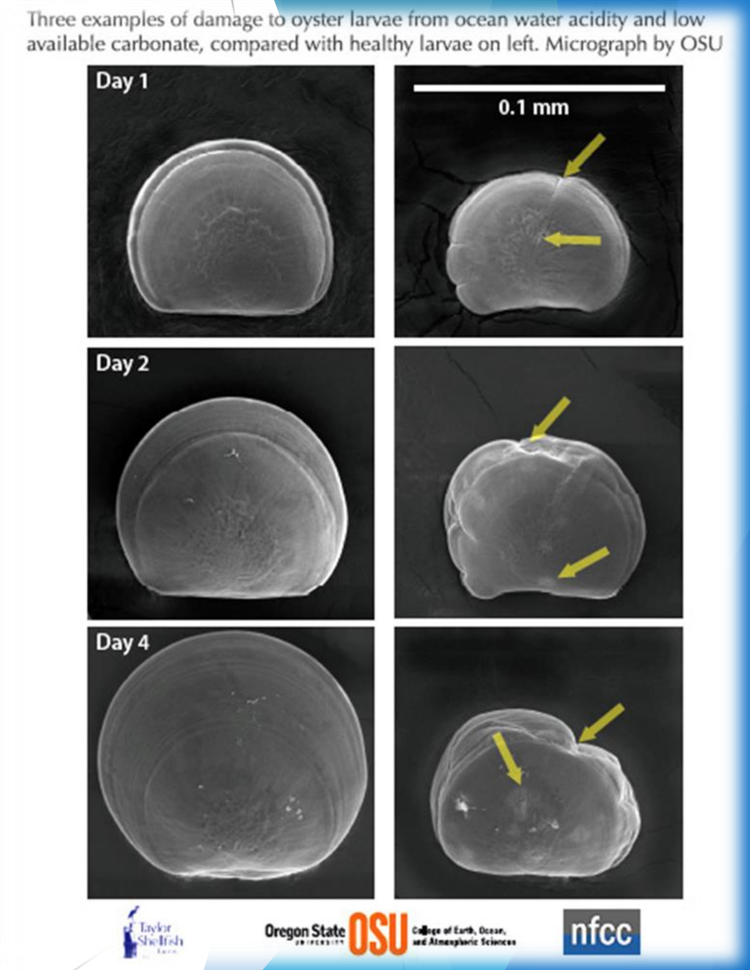
https://www.pmel.noaa.gov/co2/story/La+Push: **showing variability in PH**

Variability on coastal pH and pCO2

Less well-buffered

- Respiration
  - Phytoplankton blooms
- Storms
  - Freshwater input
  - Deep mixing
- Coastal Upwelling and other physical processes
  - Stratification (isolated water masses)

- Diurnal variability
  - Lower pH at night by 0.3

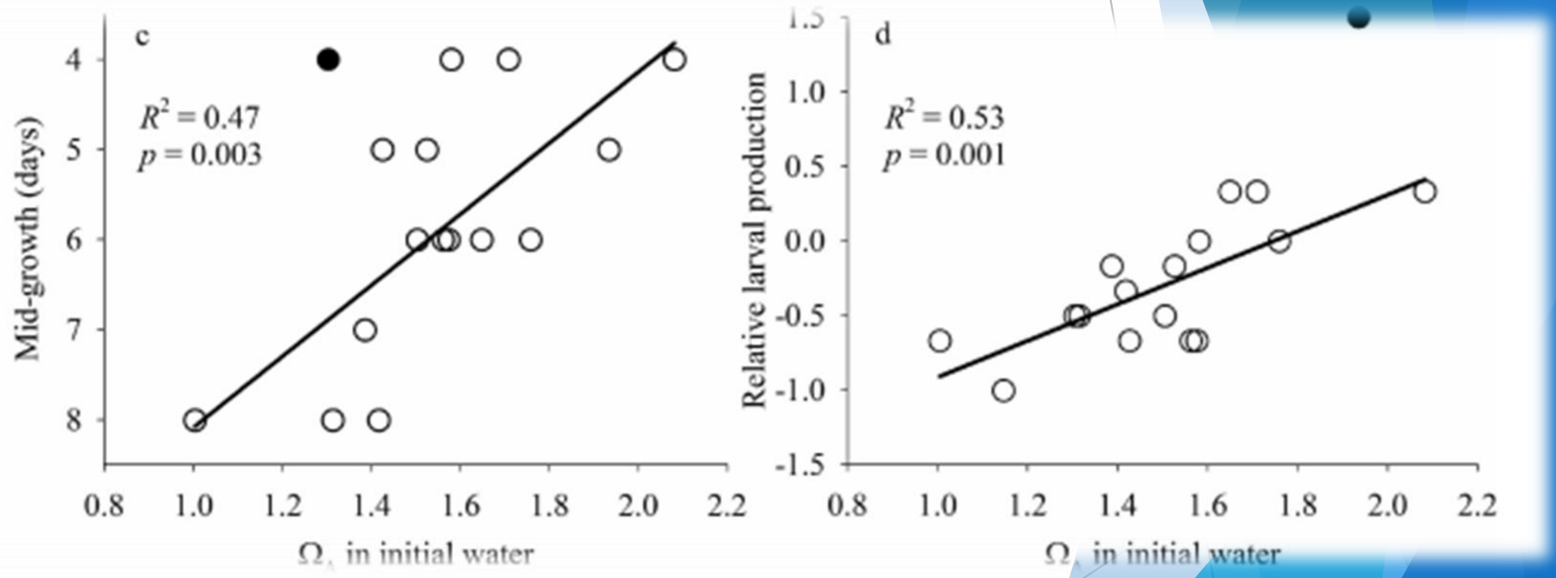


Clark and Gobbler, 2016).

Salisbury et al., 2009; Hunt et al., 2014; Gledhill et al., 2015; Salisbury et al., 2015; Kaspenberg and Hofmann, 2016

Impacts on Oysters

- Low pH yields low aragonite saturation
  - Inhibit shell development
  - Delay metamorphosis
  - Slow growth
  - Kill shellfish
- Multiple stressors
  - pH
  - Temperature
  - Food
  - Pollution



Barton et al. 2012

Impacts on Oysters

- Hatcheries treat water
  - Understanding drivers will help mangers decide on timing
- Timing in upwellers
- Moved from upwellers to mesh bags
- Remove oysters in the winter

http://blog.massoyster.org/

Approach
Specifications

- Instrument mounted on fixed pier
- Grid powered
- Pumped system – flow through
- pH and pCO_2 (SAMI-pH and SuperCO2 from Sunburst Sensors)
- Additional Temp, Salinity, CDOM, turbidity, Chl.
- Redundant local data storage
- 3G Cellular telemetry
- 10’ Interval measurements
- Daily calibration with CO_2 standards (200, 300, 400, 1000ppm)

Approach
Design Advantages

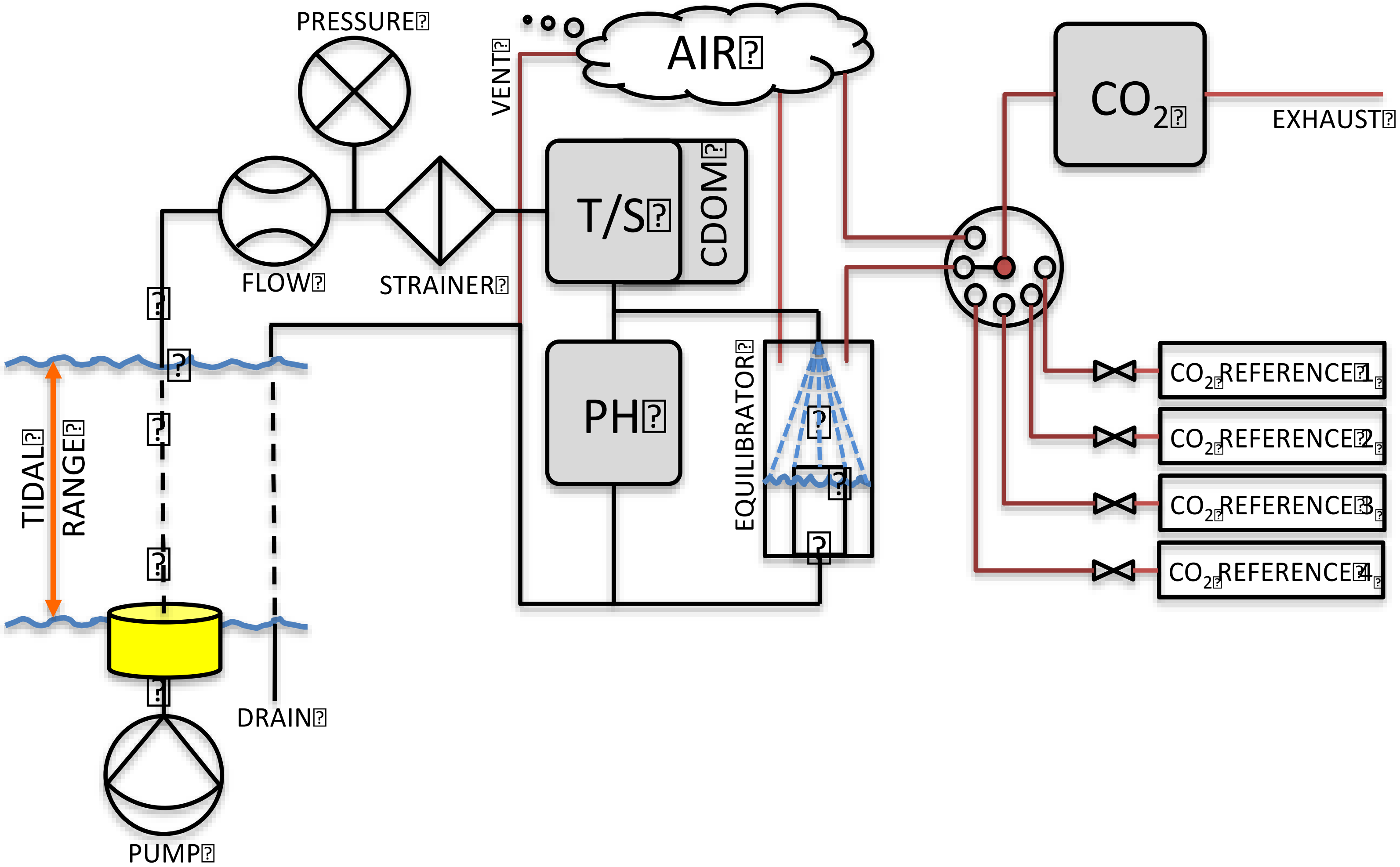
- pH: Colorimetric reagent method (SAMI-pH, Sunburst Sensors)
  - No drift
  - No calibration needed (no downtime)
- pCO_2:
  - Robust embedded LiCOR CO2 analyzer
  - Reliable dual showerhead equilibrator
- Flow-through
  - Easier to control biofouling and maintain
  - Modular (easy to add more sensors)

Approach

Design Advantages

- Dock mounted and grid powered w/ Cellular telemetry
  - Reliable platform with ease of access
  - High data collection rate
- Multi-tiered data storage
  - Up to 6 months of local storage at 10’ data collection
  - Dedicated RDMS server at UMB
  - Proposed data share on NERACOOS portal
- Climate controlled sealed enclosure
  - Ready for year-round use
  - Unobtrusive marine deck box

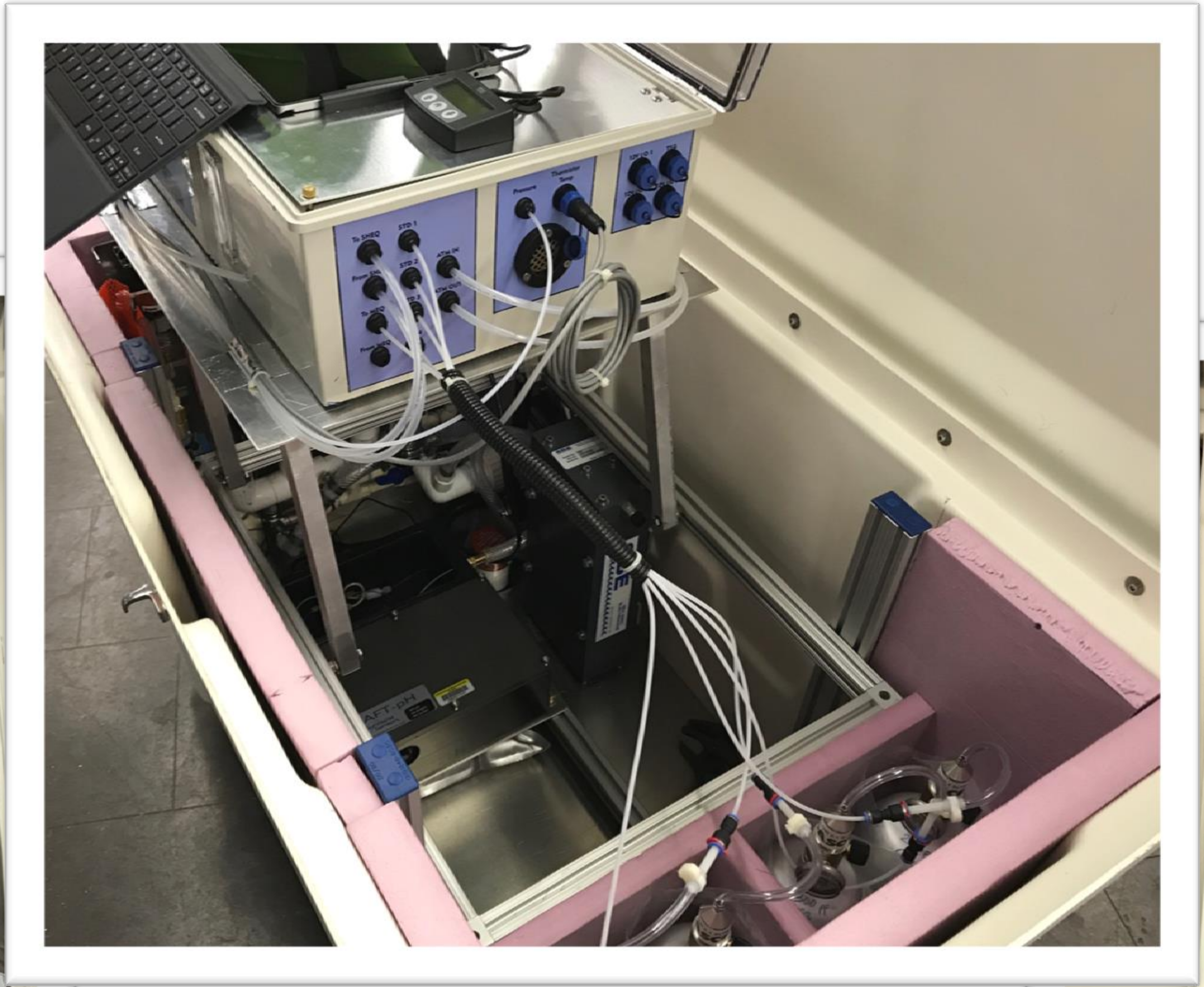
System



PRESSURE
VENT
AIR
CO2
EXHAUST
T/S
CDOM
FLOW
STRAINER
PH
EQUILIBRATOR
CO2 REFERENCE 1
CO2 REFERENCE 2
CO2 REFERENCE 3
CO2 REFERENCE 4
TIDAL RANGE
DRAIN
PUMP

System

System



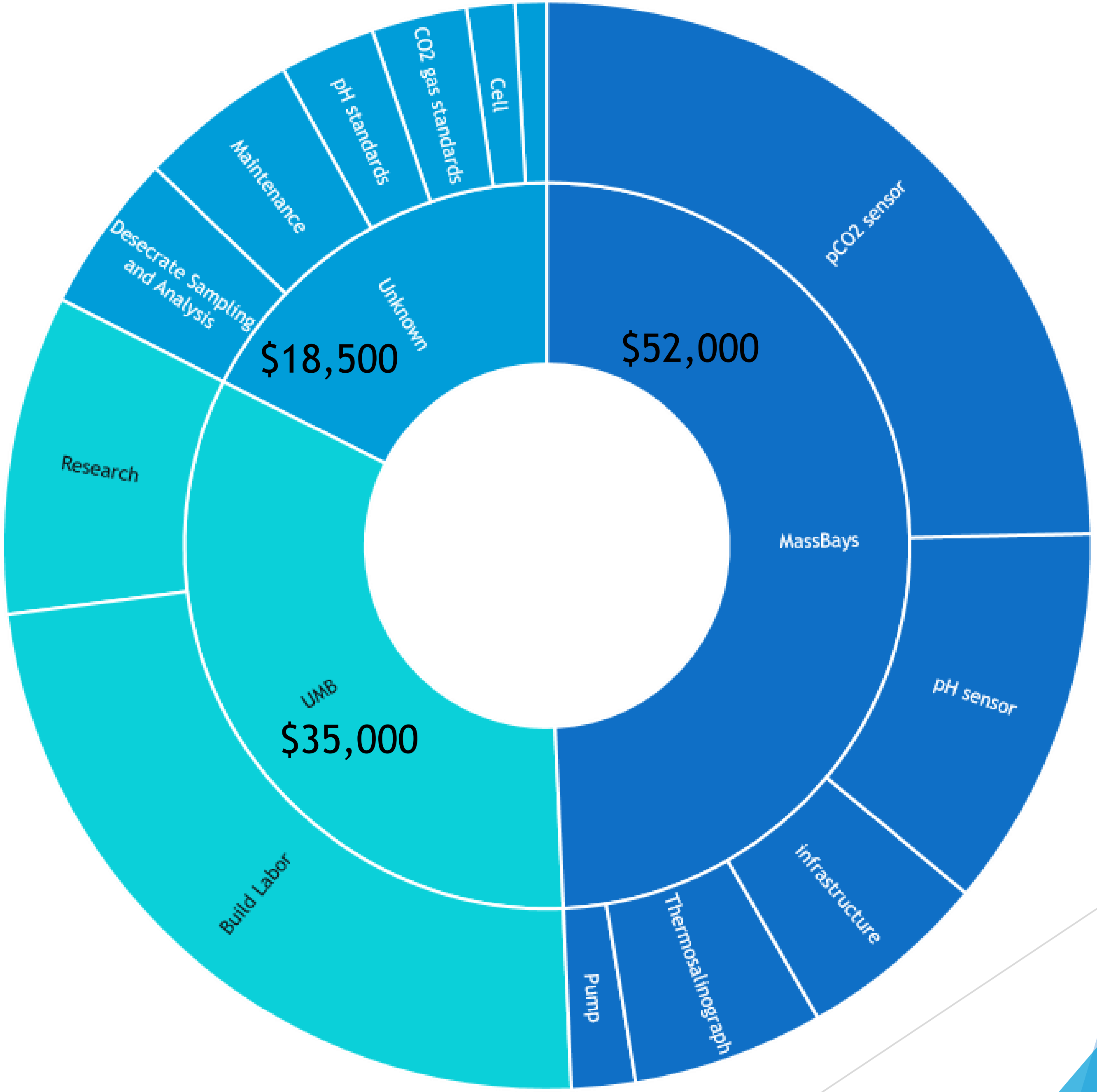
Refinements/adaptations to the site

Challenges

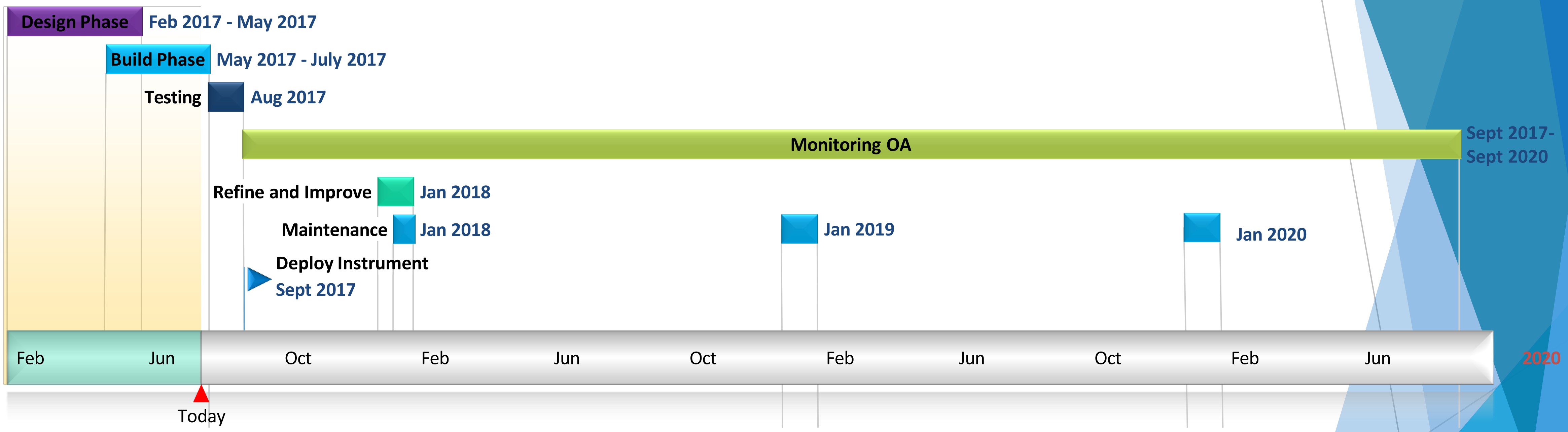
- Constant flow with 12ft tides
- What happens on exceptionally low tides
- Dock can get significant splash over during storms
- Floating pump for constant-depth sampling
- Icing control
- From prototype to production with 1 iteration
- Limited budget

Budget

Item	Cost
pCO2 sensor	26000
pH sensor	12000
Pump	2000
Thermosalinograph	6000
infrastructure	6000
CO2 gas standards	3000
pH standards	3000
Power	1000
Cell	1500
Maintenance	5000
Desecrate Sampling and Analysis	5000
Build Labor	25000
Research	10000



Project Timeline



Summary/Conclusions

- Proven pH and pCO2 sensors
- Integrated design in robust dock-side package
- Low-cost maintenance
- Integrates with additional sensors
- Provide data in near real-time
- Integrates with NERACOOS data portal
- Scheduled visits to the system to collect discrete samples to groundtruth the data

Thank you!

And Questions?